THE EVOLUTION OF A GRAVEL BAR

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One of the characteristic features of many Ozark streams is the occurrence of gravel deposits usually found on the concave bank of river-bends. It has been suggested (Anderson, 1949) that these deposits, known as "gravel bars," may evolve their own flood-control systems. An investigation of one such bar on the Meramec River, at Gray Summit, Missouri, was made in order to determine how the bar had evolved physically, and, in a general sense, how this change affected and was affected by the natural populations of the river bank.

It is generally known that the size and shape of many gravel bars is not constant, but there has been no quantitative work to show this. The determination of the physical changes of this one gravel bar necessitated the assembly of all available historical data, their reduction to a common scale, and the consequent plotting of all recorded changes. This assembly of historical data is not as difficult as it might seem. There usually exist, in offices of county engineers, fairly complete surveyor's reports which may go back 100 years or more, as at the Franklin County courthouse in Union, Missouri. In addition, the field offices of the U. S. Department of Agriculture frequently have large aerial photographs of the areas within their district. Data from these two sources, as well as some private aerial photographs, were used to chart the physical evolution of the gravel bar selected. The data follow:

Record	Date	Source
Survey record	1853	Franklin County Courthouse
Survey record	1881	Franklin County Courthouse
U. S. Geol. Surv. map	1896	Supt. of Documents, Washington, D.C.
Aerial photograph	1927	Missouri Botanical Garden
Aerial photograph	1937	Department of Agriculture
Aerial photograph	1941	Department of Agriculture
Aerial photograph	1950	Made for this investigation
Survey record	1950	Made for this investigation

The records up to 1896 indicate that the Meramec River was without bends or pattern interruptions at the point where the bar is now located. These records are supported by ground reconnaisance, which reveals traces of the old river bed. The north bank of the old river stands out especially clearly (row I in figs. 1–4), marked by a ridge on which there are trees up to 6 feet DBH. The three earliest records coincide in the position of the river, indicating that it probably did not shift significantly from at least 1853 until after the data were gathered for the 1896 geological survey. The 1927 photograph shows a distinct bend of the river, with a crescent-shaped gravel bar on the concave side, as do all subsequent photographs and the 1950 survey maps (fig. 1–4). Consequently, at some time between

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1896 and 1927, the river embarked upon a period of change with meanders developing in various places.[1]

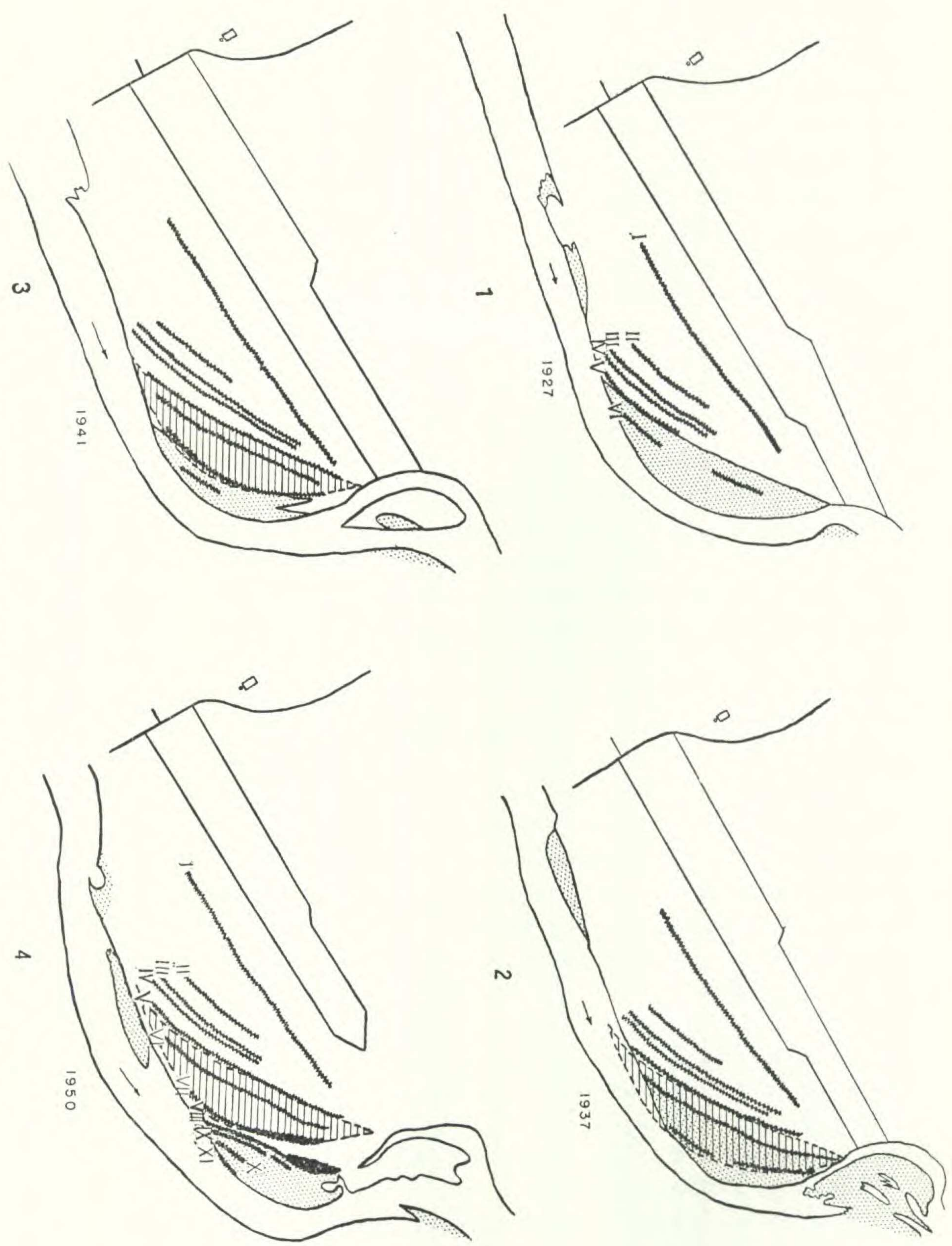
With the assembly of the data, it became necessary to reduce them to a common scale, in order to measure the changes quantitatively. An obvious solution to this problem is to photograph each reconstruction, enlarging the negatives in such a way as to establish final prints with an identical scale for each. In practice, without specialized equipment, this proved impractical. The final prints were very close to being on a common scale—within about 1 per cent—but the small differences between them made the "ground error" somewhere between 50 and 150 feet, too great for the refinement desired.

An alternate method consisted of drawing grids over the original data, with the grid lines a specified and measurable ground distance apart. Charts were then prepared with grid lines constructed equidistant on each chart. The original data were re-drawn onto the prepared charts, and were consequently on a common scale. The transferable error proved to be considerably less than the photographic error described above. Figures 1–4 are outline drawings prepared from four of the final, common-scale charts. These figures show the following facts regarding the physical changes in the gravel bar from 1927 to 1950.

The gravel bar in 1927 was about 800 feet long and 150 feet wide (fig. 1). The dark line marked with the Roman numeral I represents the line of trees along the bank of the former river-bed. In the area transect (fig. 5) these trees are marked with the key-number 12, and the remains of the river-bed with the number 11. By 1937 the bar had moved about 75 feet in a southeasterly direction, and was about 600 feet long and 200 feet wide (fig. 2). In 1941 the inland edge of the bar occupied the same position that the far bank of the river did in 1927. The downstream side of the bar remained about where it was in 1937, but the upstream portion had swung southward about 125 feet. The dimensions in 1941 were about 600 × 100 feet (fig. 3). By 1950 the shift had become nearly due east, so that the gravel bar was nearly 200 feet east of its 1927 position, and was about 500 × 110 feet in area (fig. 4). The same bar in 1952 showed marked changes since 1950. It was wider and more nearly hemispherical, and the fish-shaped bar which appears upstream in fig. 4 has extended downstream until the two bars have almost merged.

As a result of this investigation we now had available quantitative data on the physical changes of one gravel bar covering a period of twenty-three years. If we accept the supposition that the bed of the river prior to 1896 was indeed adjacent to the line of trees designated by the number I on figs. 1–4, as seems likely, then the river must have moved southward a distance of about 350 feet at the point where the upstream portion of the gravel bar was located in 1950, and

[1]Kirk Bryan (1941) propcsed cycles of aggradation and degradation by the rivers of the southwestern United States. Is our cycle hololcgous with his? There are no data and we can only speculate. Etter (1949) reported an occurrence on a creek in Pike County, Missouri, which adds some fuel to such speculation.



Figs. 1–4. Dot shading shows current gravel deposits; line shading shows 1927 bar location in subsequent years. Further explanation in text.

developed a meander—on which the bar is located—back to, and a little beyond its old course in the intervening half-century or so.

Although this investigation was primarily concerned with the story of the physical change of the gravel bar, the action by the river has had a profound effect on the ecology. A critical observer on the spot, even without prior information on the spbject, can discern without difficulty that willows play an important part in the over-all story of the gravel bar. These shrubs and trees bear directly upon the physical evolution of the bar itself, and the land area behind it.

During the late spring and early summer, when the willows are in fruit, the river surface may be covered with the cottony floating seeds. Willow seeds are viable for only a short period of time, about three or four days according to the U. S. Dept. Agr. "Woody Plant Seed Manual." If conditions are right, some of these floating seeds may give rise to a new line of willows at the water's edge. Briefly, the "right conditions" appear to be these: (1) the river receding after a flood, but still slightly higher than normal, and (2) viable seeds being left on the gentle slope of the moist shore line by the retreating waters. If the seeds remain moist they may germinate, and if the river does not again flood and tear the seedlings out before they have become established, within a few months they will become small saplings. After they have become established, even severe floods fail to dislodge them. The result is a line of willow saplings at the water's edge. In the late spring of 1949 conditions were right for the establishment of willow seedlings, and the writer observed a deposition of seeds. The next spring there was a row of supple saplings, which, due to flood conditions at that time, were several feet out into the water. An attempt to dig up the saplings, with the aid of a shovel and river action, augmented by pulling from above, failed to dislodge a single one.

At the same time it was observed that the swollen stream was gouging out the substrate on both sides of the line of willow saplings. The substrate among the seedlings was not being eroded due to the cohesive action of the willow root systems, but on the contrary, the aerial stems of the willows were slowing down the rate of flow through them to the point where sand and silt were being deposited along the line on which they were growing.

As one walks away from the shore line, several lines of willows may be seen, each on a ridge, with channels between them gouged out by flood action. These lines of willows were apparently deposited in the same manner as described above, and therefore represent the shore line of the gravel bar in times past. Ring counts substantiate this hypothesis. In 1950, seven-year-old willows were found in a line approximating the 1941 shore line, and 10-year-old willows formed a line slightly inside the 1941 shore line.

Three species of willows were involved in the gravel bar studied—*Salix interior (S. longifolia)*, *Salix caroliniana (S. longipes* var. *Wardi)* and *Salix nigra.* For the last species, only one deposition occurred, apparently before 1935, but the other two had occurred at intervals over that same period. The lines on the map (fig. 1–4) correspond to observable rows of trees. The line marked VIII was largely S. *interior*, that marked IX was largely S. *caroliniana*. Line VII contained S. *nigra*, *Acer saccharinum*, *Ulmus fulva*, *U. americana*, and *Populus deltoides*. Inland from line VII there were no willows. In this area the ridge furrow topography is occasionally preserved, although discerned only with difficulty. Those which are observable are marked on the illustration (figs. 1 and 4) with Roman numerals. The numbers run from I (the presumed bank of the river during the nineteenth century) to XI (the water's edge in 1950). These features tell the story of successive changes in river position since the change began. Figure 5 shows a cross-section of the area from the middle of the gravel bar northwest to the old river bank. Well-developed stream-bend gravel bars present an example of spatial succession, similar to that observed in such places as the dunes region of lower

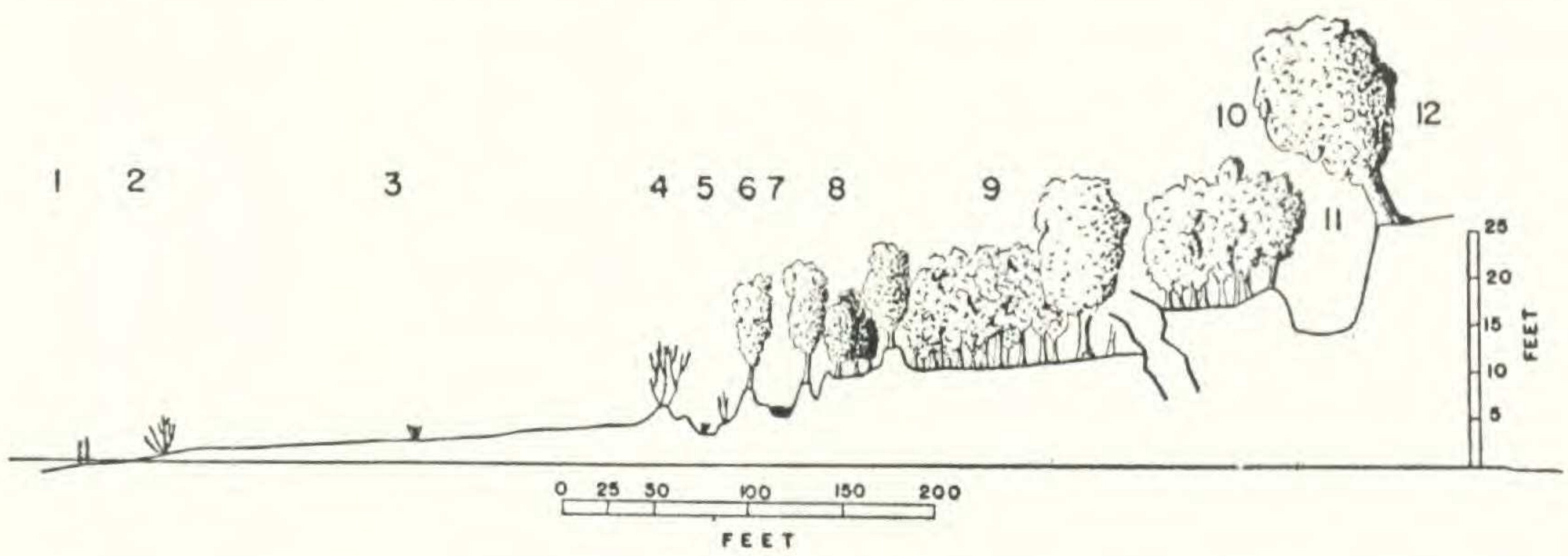


Figure 5. Explanation in the text.

Lake Michigan. In fig. 5, from the water's edge inward, we see: (1) Water Willow, *Dianthera americana*, a transient plant which is ripped out by severe floods; (2) willow seedlings of various species, the first permanent plants; (3) the strand, generally barren gravel and sand, on which the permanent plants are willows, *Amsonia illustris*, and *Panicum virgatum;* (4) and (6) ridges on which are large willows; (5) and (7) fosses or canals, gouged out by flood action, in which *Panicum* and *Amsonia* are permanent residents, as on the strand, although in the fosses they tend to slow down the flood water, resulting in the eventual filling up of these areas by deposition; (8)–(10) the area in which willows are replaced by cottonwoods, elms, and maples, roughly in that order; (11) the old river bed; and (12) the row of large old sycamores, maples, etc. making up the old river bank.

Since the three species of willows growing on this one gravel bar generally flower at different times in normal years, there are three chances during a year for conditions to be such that a line of willows could become established. Ring counts of the oldest solid line of willows (Ridge VIII) indicate that seeds for these were deposited in 1940. In the ten years from 1940 to 1949, inclusive, there were thirty chances for willows to become established. Actually, only four lines were successful, although some lines contain two species, indicating a seedling success rate of about 13 per cent, at least as far as the establishment of a new physical line is concerned.

As previously noted, Anderson suggested that some gravel bars evolve their own flood-control systems. The writer's observations indicate that such appears to be true of the bar studied. In times of flood the water is spread out and channeled through the fosses. Those farthest from the river eventually become choked up with plants, but in the fosses of intermediate distance only such plants as *Amsonia illustris* and *Panicum virgatum* can exist through flood periods. Like the willows on the ridges, these plants are not torn out by severe floods, and they seem to serve to slow down the rate of flow in the furrows as the willows do on the ridges. More of this slowed-down, channeled water seeps into the ground, and run-off is lessened. In 1949 beaver *(Castor canadensis)* made use of one of the fosses, damming it up and creating a small pond behind it. The dam has survived several floods. By 1952 the beavers had moved on to another area, but their dam still serves to augment the other natural flood-control features of the gravel bar area.

SUMMARY

A gravel bar on the Meramec River at Gray Summit, Missouri, has been studied from the standpoint of changes in shape and location. Maps and aerial photographs covering a period of 97 years were employed. From the first record of a gravel bar on a 1927 photograph until 1950, the evolution of this bar has been studied quantitatively. It has changed in size from about 800 $\times$ 150 feet to about 500 $\times$ 110 feet. It has changed in position to a point about 200 feet east of its former location.

These changes are confirmed by an analysis of the ridges and fosses on the surface of the bar and the adjacent areas. These features are caused by the resistance of willow saplings to dislodgement when once established. This leads to the development of a ridge and fosse topography which provides natural levees and spillways for the river. Since the willows are originally laid down on the shore line, we have a record in the ridge and fosse topography of the changing shore lines over a period of years.

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